Reply to comments on "Machine-learning models of $\delta^{13}C$ and $\delta^{15}N$ isoscapes in Amazonian wood" by Souza-Silva et al.

We are grateful to the editor and reviewers for their thorough assessment of our manuscript. Their detailed feedback and thoughtful suggestions have been instrumental in refining the study. We have carefully addressed all comments and outline our responses below.

Referee 2

General comments

As a stable-isotope researcher with >15 years of experience, I read the work by Souza-Silva et al. on "Machine-learning models of $\delta^{13}C$ and $\delta^{15}N$ isoscapes in Amazonian wood" with great interest. The authors deliver an exceptionally valuable resource to the community: isotopic measurements for >550 trees distributed across 47 Amazonian sites, coupled with a robust Random-Forest framework that links wood $\delta^{13}C$ and $\delta^{15}N$ to 74 environmental predictors. The rationale is sound and the methodology state-of-the-art. I therefore strongly recommend its publication. Nevertheless, two issues merit attention before the manuscript reaches its full potential.

Response: We sincerely thank the reviewer for this very positive and thoughtful assessment of our work. We appreciate the recognition of the dataset, the methodological framework, and the potential value of these isoscapes for the community. Below we address the specific points raised.

Specific comments:

1. Basin-scale timber provenancing: although the $\delta^{13}C$ and $\delta^{15}N$ isoscapes represent a commendable advance, their ability to discriminate Amazonian from non-Amazonian timber (or other regions within the Amazonian) remains equivocal. The observed intra- and inter-site variability is sufficiently large that isotopic signatures from other tropical forests may fall within the Amazonian envelope. I therefore urge the authors to (i) incorporate a comparative dataset of timber collected outside the basin and (ii) provide quantitative classification metrics (sensitivity, specificity) to rigorously demonstrate—and transparently bound—the utility of the isoscapes for large-scale provenance assignment.

Response: We thank the reviewer for this important and carefully articulated comment. We acknowledge that comparative analyses involving timber collected both within and outside the Amazon basin constitute an ambitious and valuable approach for addressing questions related to inter-basin discrimination and global provenance frameworks. Nevertheless, the aim of the present study is not to test the discrimination between Amazonian and non-Amazonian timber, but rather to establish isotope-specific reference isoscapes for $\delta^{13}C$ and $\delta^{15}N$ in Amazonian wood and to investigate the environmental processes controlling their spatial variability across the basin. These isoscapes are intended to provide a reference framework that can support future timber traceability studies, while also advancing the understanding of biogeochemical dynamics across the Amazon region. Addressing point (i), namely the incorporation of non-Amazonian datasets, would therefore represent a distinct and substantially more demanding research objective, requiring a broader sampling effort and a fundamentally different experimental design, including harmonized external datasets and supervised classification protocols, which lie beyond the scope of this manuscript. With respect to point (ii), we recognize that $\delta^{13}C$ and $\delta^{15}N$ alone are insufficient for definitive provenance verification, particularly at fine spatial scales. As discussed in the manuscript, these isotopes are best viewed as complementary tracers that support regional-scale monitoring and preliminary screening. More robust provenance assignment is expected to arise from multi-isotope frameworks integrating tracers that convey independent environmental information, such as strontium and sulfur. In this context, a bioavailable strontium isoscape for the Amazon basin has recently been developed (Martinelli et al., 2025), providing a solid foundation for future multi-isotope provenance applications. Such frameworks will be better suited for the implementation of formal classification analyses and for the calculation of quantitative performance metrics (e.g., sensitivity and specificity), as suggested by the reviewer.

2. Conciseness and focus: the manuscript, in its present form, is unduly verbose. Lengthy expositions in the Introduction, Results, and Discussion dilute the key messages and obscure the novel contributions. I strongly recommend a comprehensive tightening of the text—prioritizing only the most essential

findings and their implications—to enhance clarity, readability, and impact for the broad readership of this journal.

Response: We thank the reviewer for this constructive recommendation. We fully agree that improved conciseness will strengthen the manuscript. In response, we have carefully revised the Introduction, Results, and Discussion to reduce redundancy, remove less essential narrative elements, and sharpen the focus on the most relevant findings and their broader implications.

Reference

Martinelli, L., Bataille, C., Batista, A., Souza-Silva, I., Araújo, M., Abdalla Filho, A., Brunello, A., Tommasiello Filho, M., Higuchi, N., Barbosa, A., Costa, F., and Nardoto, G. (2025). *Bioavailable strontium isoscape for the Amazon region using tree wood*. **Forest Ecology and Management**, 594, 122963. https://doi.org/10.1016/j.foreco.2025.122963.